



Earth Science Enterprise Technology Planning Workshop

On-Board Processing

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January 24-25, 2001



Onboard Processing

Focus:

- Technologies needed for data compression, event recognition and response, hyperspectral and radar data onboard processing, and the required processor and memory requirements

Aspects of technology requiring validation:

- Fault-tolerant computing and processor stability
- Autonomous event detection and response
- Situation-based data compression and processing



Agenda

Tuesday, January 23, 2001

Introduction, Overview

Science and technology presentations

Real-time earthquake detection

Frank Vernon (UCSD)

On-board architecture

Jason Hyon (JPL)

Recap of the AIST Technology Projection Workshop, August 2000

Loren Lemmerman (ESTO)

Hyperspectral applications

Robert Ferraro (JPL)

Superconducting applications

Jerome Luine (TRW)

Software-implemented fault tolerance

Michael Lovellette (NRL)

Image feature identification

Michael Turmon (JPL)

Autonomous operations

Michael Swartout (Washington University)

Radar applications for global precipitation

Eastwood Im (JPL)

Discussion and interim summary of issues

Wednesday, January 24, 2001

Identify convergence of science needs and candidate technology

Define specific capability/technology needs

Identify ongoing investments and development gaps

Formulation of draft technology development roadmaps

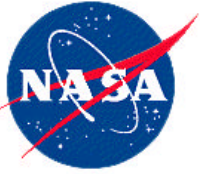
flight/ground validation required?

Potential validation missions



Workshop Participants

Name	Affiliation	Name	Affiliation
Aljabri, Abdullah	JPL	Lovellette, Michael	NRL
Allen, Mark	Honeywell	Luine, Jerome	TRW
Andrews, David	U. Kansas	Mills, Carl	LaRC
Barfield, Joe	South west Res. Inst.	Minning, Chuck	JPL
Brambor a, Cliff	GSFC	Pedersen, Barbara	Computer Sciences Corp.
Brown, Larry	Motorola	Salay, David	Battelle
Burke, Tom	Northrop-Grumman	Smith, Dan	General Dynamics
Caprio, Cesare	BAE Systems	Swartwout, Michael	Washington U.
Chu, Kai-Dee	ESTO	Travler, Ann	OSL
Coleman, Tommy	Alabama A&M	Turmon, Michael	JPL
Ferraro, Robert	JPL	Vernon, Frank	UCSD
Hyon, Jason	JPL	Wilcox, Jaroslava	JPL
Im, Eastwood	JPL	Wood, Kent	NRL
Lee III, Robert B.	LaRC	Wyatt, Jay	JPL
Lindell, Scott	Lockheed-Martin		



Session Approach

- The first day covered:
 - Sample science and mission applications which drive the technology
 - A range of typical technology options for on-board processing
 - Recent results from similar technology workshops
- After the science and technology presentations, session participants developed a list of key topics in on-board processing
- From these topics, a range of potential technology validation experiments/missions was developed



Categories of on-board processing technology topics

Integrated System Space Test: System-Level Test	No In-space Integrated Systems Test Needed
<p><i>Autonomy</i></p> <ul style="list-style-type: none"> • Communications Node (Standard switched packet node) • Mission Priorities • Science Event Handling • On-Board Resource Management • Autonomous Formation-keeping • On-Board Adaptive Data Management • On-Board Feature Recognition • On-Board Science Decision-Making <p><i>Reduce communication bandwidth</i></p> <p><i>Reduce costs</i></p> <ul style="list-style-type: none"> • Radiation-Tolerant Processors (with Fault Tolerance) • Fault Tolerant Operating Systems for Space Processing • Synchronization <p><i>Reduce data latency</i></p> <ul style="list-style-type: none"> • Real-Time Performance <p><i>Radical new technology</i></p> <ul style="list-style-type: none"> • MEMS Systems 	<ul style="list-style-type: none"> • Radiation-Hardened Processors • Calibration (Data Handling) • Framework Architecture • Risk Assessment • On-Board Self Tests • Reconfigurable Processor Programming Language • Terrestrial COTS Packages • Low-power Libraries • Memory Technology • Frameworks • Open Source Operating Systems • Data Compression • Data Reduction • Reconfigurable Processors • High-Speed Data Buses (Network Interface Device)



Potential for technology validation missions

- Hardware-related missions:
 - Radiation tolerant processors
 - Communications node (package switching) / radiation tolerant network interface
- Software-related missions:
 - Autonomous spacecraft-level mission operations
 - Payload (instrument-specific) systems



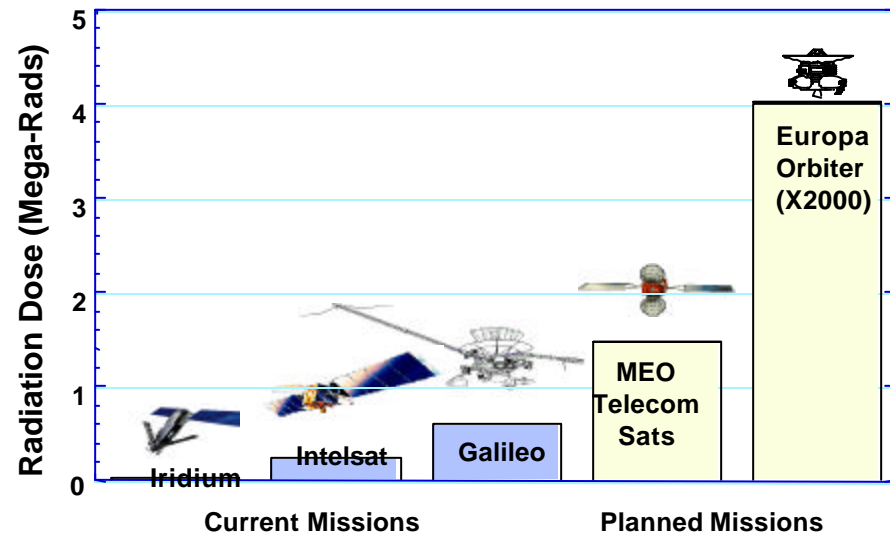
Requirements for: Radiation Tolerant Processors

The Challenge:

Need radiation tolerance (~100Krad)
within one generation of current
technology with reliability of rad-
hardened

Potential Future ESE Missions:

- VISION



Technology Approach:

- Software/hardware augmentation for SEE/SEU susceptibility
- Radiation-tolerant libraries

Drivers for Flight Validation:

- Cannot reproduce space environment on ground



Validation Experiment for: **Radiation Tolerant Processors**

Objective:

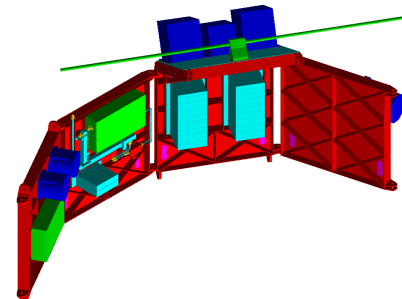
Demonstrate system reliability, quantify improvements

Top-Level Development and Flight Schedule

1. Find “new” hardware (Year 1)
2. Develop fault tolerant operating system (Year 2)
3. Formal ground test (Year 3)
4. Perform space experiment (Year 4)

Scope:

- Piggyback on long-term mission.
- Multiple processors

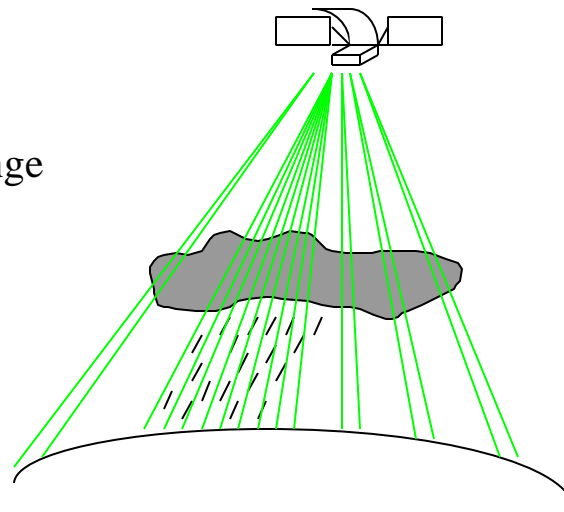




Requirements for: **Communication Node/Radiation Hardened Networks**

The Challenge:

- Communications Node/
Radiation tolerant network
interface
- Allow common data exchange
architecture
- Distributed systems



Potential Future ESE Missions:

- Global precipitation mission
- Any multi-platform mission

Technology Approach:

- Develop common network node to fly
on multiple spacecraft
- Develop a packetized, high speed rad-
hard data bus

Drivers for Flight Validation:

- Can't reproduce on the ground because of
distances and geometry
- Develop high-speed communication
components



Validation Experiment for: **Communication Node/Radiation Hardened Networks**

Objective:

- Demonstrate a working spaceborne network (packet switching core)
- Demonstrate a standard component interface

Top-Level Development and Flight Schedule

1. Develop network architecture
2. Develop hardware architecture for switching
3. Develop communications architecture
4. Develop Routing software and protocols
5. Fly (would take about 2 years to build)

Scope:

- Piggyback multiple spacecraft/missions



Requirements for: Autonomy Systems (Spacecraft level)

The Challenge:

(For Planning):

- Autonomous spacecraft control
- Software for autonomous mission operations

(For Interesting Targets):

- Feature extraction

Technology Approach:

(For Planning):

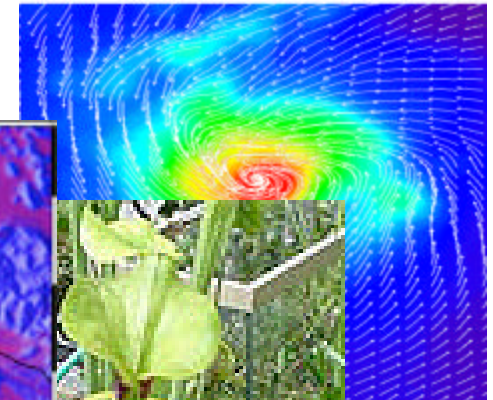
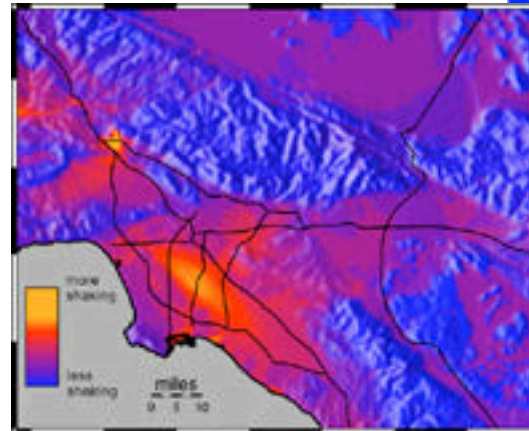
- Onboard planning and scheduling
- Synchronization
- Hazard checking
- Resource management
- Event handling

(For Interesting Targets):

- Target handoff
- Region classification
- Template matching
- Model-based identification

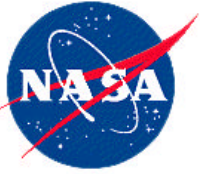
Potential Future ESE Missions:

- Sensor Webs
- Land Cover Inventory
- Hazard detection



Drivers for Flight Validation:

- Long term system level complexity: faults, asynchronous processing, latency
- Target handoff to other spacecraft and instruments
- Ability to use identified features in planning



Validation Experiment for: **Autonomy Systems (Spacecraft level)**

Objective:

- Multisensor fusion/web
- Hooked to an incremental planner

Top-Level Development and Flight Schedule

1. Develop software requirements (Year1)
2. Develop software (e.g., target processing algorithm)
3. Run planner on ground
4. Run piggyback mission
5. Run multi-spacecraft mission (2005 timeframe)

Scope:

- Value-added multiple sensor mission
- Could be dedicated or piggyback



Requirements for: **Payload Systems (instrument specific)**

The Challenge:

- Data reduction
- More effective bandwidth utilization
- Fault tolerant and robust

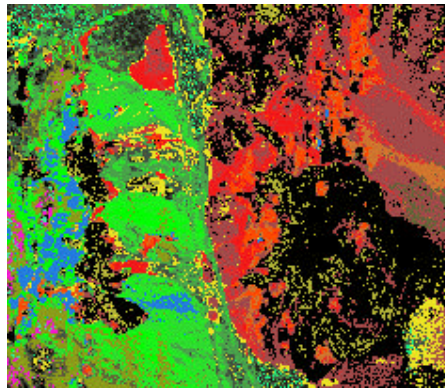
Technology Approach:

Develop common packages for

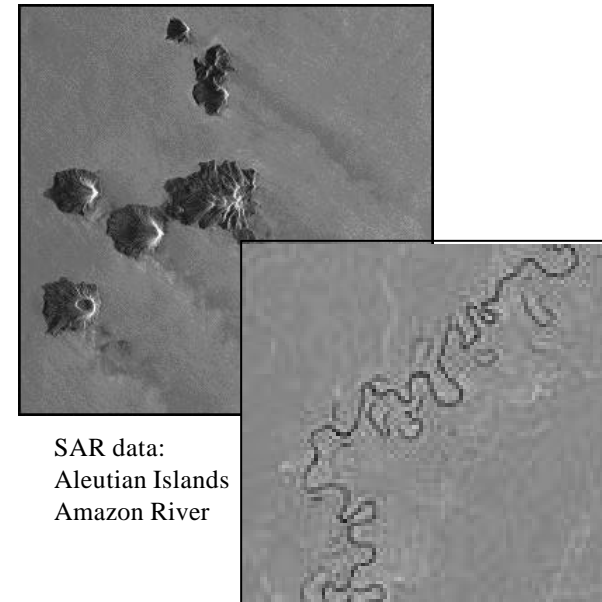
- data compression
- Fourier transforms
- selection and segmentation

Potential Future ESE Missions:

- Hyperspectral instruments
- Large data intensive systems (SARs)



AVIRIS data:
Mineral map,
Cuprite, Nevada



SAR data:
Aleutian Islands
Amazon River

Drivers for Flight Validation:

- Validate fault models, reliability, accuracy
- Scientific acceptance: demonstrate robustness



Validation Experiment for: **Payload Systems (instrument specific)**

Objective:

- Demonstrate advanced fault-tolerant software
- Dramatic reduction in downlink bandwidth or increased use of existing link
- Quantify and enable new science - 10x or more

Top-Level Development and Flight Schedule

1. Science collaboration
2. Could fly soon - new hardware development not necessary

Scope:

- Value-added to appropriate missions (hyperspectral, Firesat)
- Could be piggyback



Summary Tables

TECHNOLOGY DESCRIPTION			VALIDATION EXPERIMENT			
Future Mission Type (ESE Mission applicability)	Challenge Description	Technology Approach	DRIVER(S) FOR FLIGHT VALIDATION	OBJECTIVE	SCOPE	MILESTONES
VISION	Need radiation tolerance (~100Krad) within one generation of current technology with reliability of rad-hardened.	Software/hardware augmentation for SEE/SEU susceptibility	Cannot reproduce space environment on ground	Demonstrate system reliability, quantify improvements	Piggyback on long-term mission. Multiple processors.	1. Find "new" hardware (Year 1) 2. Develop fault tolerant operating system (Year 2) 3. Formal ground test (Year 3) 4. Perform space experiment (Year 4)
		Radiation-tolerant libraries	none			
Global Precipitation Mission, any multi-platform mission	Communications Node/ Rad tolerant network interface	Develop common network node to fly on multiple spacecraft	Can't reproduce on the ground because of distances and geometry	Demonstrate a working spaceborne network (packet switching core)	Piggyback multiple spacecraft/missions	1. Develop network architecture 2. Develop HW architecture for switching 3. Develop comm arch 4. Develop Routing SW/protocols 5. Fly (2 years to build)
	Allows common data exchange architecture Distributed systems	Develop a packetized, high speed rad- hard data bus	Develop high-speed communication components	Demonstrate a standard component interface	Any host mission - (piggyback)	same as above



Summary Tables (Cont.)

TECHNOLOGY DESCRIPTION			VALIDATION EXPERIMENT			
Future Mission Type (ESE Mission applicability)	Challenge Description	Technology Approach	DRIVER(S) FOR FLIGHT VALIDATION	OBJECTIVE	SCOPE	MILESTONES
Sensor Webs, Land Cover Inventory, Hazard detection (earthquake, buoys)	(Planning) Autonomous spacecraft contro; SW for autonomous mission operations	Onbd planning scheduling, synchronization, hazard checking, resource mgmet, event handling	Long term syteem level complexity, faults, asynchronous processing, latency	Multisensor fusion/web; hooked to an incremental planner	Value-added multiple sensor mission (could be dedicated or piggyback)	1. Develop SW reqts (Year1) 2. Dev software (e.g., target processing algorithm) 3. Run planner on ground 4. Run piggyback mission 5. Run multi-SC mission ['05 timeline]
	(Interesting targets) Feature Extraction	Target handoff, region classificaton, templated matching, model-based	Target handoff to other spacecraft and instruments. (Instrument specific). Ability to use identified features in planner in previous line).			
Hyperspectral instruments, large data intensive systems (SARs) [SW-inst]	Data reduction, more effective bandwidth utilization, fault tolerant and robust	Develop common packages for data compression and Fourier transforms, selection and segmentation	Validate fault models, reliability, accuracy. Scientific acceptance: demonstrate robustness	Demonstrate advanced fault-tolerate software. Dramatic reduction in downlink bandwidth or increased use of existing link. Quantify and enable new science - 10x or more.	Value-added to appropriate missions - hyperspectral, Firesat. Could be piggyback.	1. Science collaboration. Could fly soon - new hardware development not necessary.